Tropical Atlantic biases in the mean state, seasonal cycle, and interannual variations for a coarse and a high resolution coupled climate model

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Using two fully coupled ocean-atmosphere models (the Climate Model version 2.1 developed at the Geophysical Fluid Dynamics Laboratory, GFDL-CM2.1: an Intergovernmental Panel on Climate Change Fourth Assessment Report (IPCC-AR4) model and basis of GFDL's experimental seasonal to decadal forecast system, and CM2.5: a new high-resolution global climate model based on CM2.1), the tropical Atlantic biases in the mean state, the seasonal cycle, and the interannual variations were investigated.

Many aspects of the simulation are significantly improved in CM2.5 relative to CM2.1–yet others persist. CM2.5 successfully reproduces the annual mean and the seasonal cycle of the rainfall over the Sahel and the northern South America (Figs 1 and 2), a subsurface doming of the thermocline in the northeastern tropical Atlantic (known as the Guinea Dome), and the seasonal phase-locking of the interannual variations of the northern tropical Atlantic (Fig. 3). This marked improvement is mainly due to a significant reduction of some biases in the seasonal meridional migration of the Intertropical Convergence Zone (ITCZ).

At this stage, we do not know whether the increased resolution and changes to parameterizations and numerics in CM2.5 have acted to reduce these biases directly through a better representation of the local small-scale processes or through an overall improvement to tropical and global climate. Nevertheless, the differences between CM2.5 and CM2.1 were not sufficient to reduce the SST biases in the eastern equatorial region and Angola-Benguela Area (Fig. 1), the former being a ubiquitous bias that is found in almost all IPCC-AR4 models. A tendency for weak trade winds along the equator and the weak southerly winds along the southwestern African coast are likely causative factors for these biases. Since biases may arise and be amplified by air-sea-land coupled process, it is difficult to specify the ultimate origin of the wind biases. At this stage, we speculate that the problems are mostly related to atmospheric physics associated with either deep convection or cloud processes in the AGCM. Sensitivity experiments for reducing the tropical Atlantic biases are being conducted as part of GFDL's research program.

Fig. 1

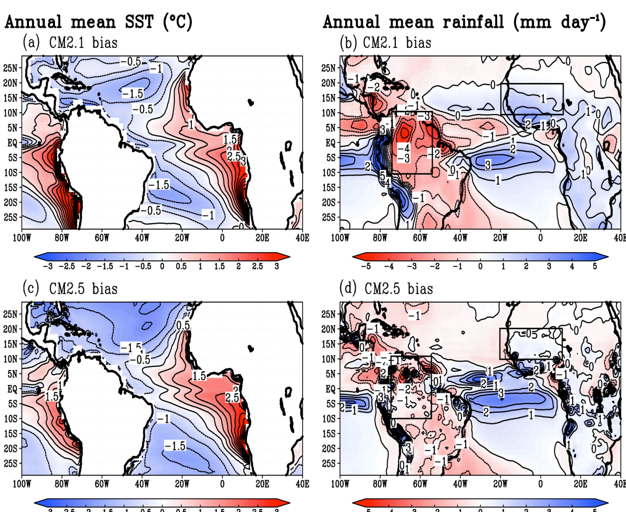

Fig. 1: (a) Annual mean SST bias in CM2.1 from observed SST of the ERSSTv3 data (°C). The contour interval is 1°C. (b) Annual mean rainfall bias in CM2.1 from the observed rainfall of the CMAP data (mm day^{-1}). The contour interval is 1mm day^{-1}. The Sahel rainfall region (20°W-10°E, 10°-20°N) and the northern Brazil region (75°-55°W, 10°S-10°N) are shown by boxes. (c) Same as (a), but for CM2.5. (d) Same as (b), but for CM2.5.

Fig. 2

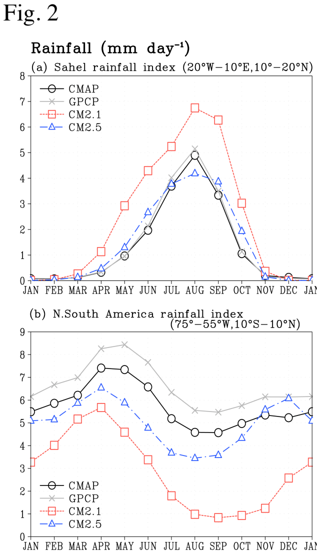

Fig. 2: (a) Annual cycle of rainfall averaged in the Sahel region (20°W-10°E, 10°-20°N) (mm day^{-1}). (b) Same as (a), but for the northern South America region: 75°-55°W, 10°S-10°N.

Fig. 3

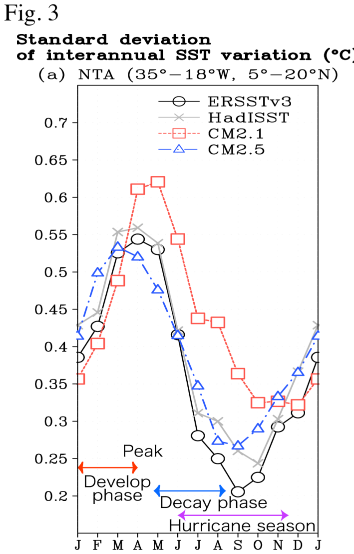

Fig. 3: (a) Monthly standard deviation of the interannual variation of SST averaged in the northern tropical Atlantic region (NTA: 35°-20°W, 5°-20°N) from ERSSTv3 (bar), HadISST (grey line), CM2.1 (red line), and CM2.5 (blue line) (°C).